

Experiment 1

Network Externalities

Having your own telephone isn't of much use if your friends don't have a phone. What good is a fax machine if the people you want to send stuff to don't have a fax? Being able to send and receive e-mail is valuable only if the people with whom you want to correspond have e-mail. The World Wide Web becomes far more useful as more people use it.

The technology for the fax machine was developed by inventors in Scotland and in Italy about 150 years ago. As recently as 1980, fax machines were still rare. Suddenly in the mid-1980's the demand for fax machines exploded, and today they are commonplace. The first session introduces the idea of network externalities and explores the workings of a market for a good that becomes more valuable to everyone as more people purchase it.

How did Microsoft come to dominate the market for computer operating systems at the expense of Apple? What became of WordStar, Visicalc, and Lotus 1-2-3? How did Bill Gates get so rich? The second and third sessions of this experiment feature fierce battles for market supremacy between competing computer operating systems, in an environment where the strong are likely to devour the weak.

Instructions

Session 1: A Network of Picture Phones

In Session 1 you will participate in a market for Picture Phones. These are telephones that send and receive pictures of the conversing parties. You can talk on a Picture Phone with someone only if both of you have Picture Phones. Your Buyer Value for a Picture Phone therefore depends on the number of other people who also have these phones.

Your *Initial Value* for a Picture Phone is given on your Personal Information Sheet. (About 1/6 of the people in the room have each of the possible initial values running from 1 to 6.) Your Buyer Value will depend both on your Initial Value and on the total number of phones sold, according to the formula:

$$\text{Buyer Value} = \text{Initial Value} \times \text{Network Externality Factor},$$

where the *Network Externality Factor* depends on the total number of demanders who buy a Picture Phone. Your instructor will post a table showing exactly how the Network Externality Factor is determined by the number of purchases.

In each round of this session the market manager will post a fixed price for Picture Phones. If you want to buy a Picture Phone at the posted price, you should register your ID number on the manager's Sales Record Sheet. Once you have purchased a phone, you will be asked to move to a designated area of the room, so that others can see how many people have bought phones so far. Your Buyer Value will be determined by the total number of people who bought Picture Phones during the round. Your profit (or loss) will be your Buyer Value minus the price you paid.

Session 2: Competing Standards in Computers

In this session there will be three sellers of computer operating systems. Demanders must decide which operating system, if any, to buy. Buyers will have network externalities only with people who buy the same operating system. People with different operating systems are not able to exchange files and other information as cheaply and easily as those with the same operating system. Your instructor will post a table showing the way that Buyer Values for each operating system are related to the number of persons who purchase the product.

Buyers' Profit Information

When you first buy an operating system, you have to pay not only the price charged by the seller but also a learning cost of \$15. (As you may know from experience, learning to use a new operating system is time-consuming and costly.) In subsequent rounds, you must either buy an updated version of your current system from the seller who sold it to you or switch to another system. If you update the operating system that you had in the previous round, you won't have to pay the learning cost. But if you change operating

systems from one round to another, you will have to pay the \$15 learning cost as well as the price charged by the supplier. To find your profits, subtract the sum of the price you pay for the operating system and your learning cost (if any) from your Buyer Value.

Sellers' Profit Information

Sellers of operating systems have a marginal cost of \$5 for each unit they sell. When they first open for business, they must pay a fixed cost of \$75. At the end of each round, sellers will have the option of going out of business. After the first round, for each round that they remain in business, sellers must pay an additional fixed cost of \$50 (for advertising and promotion) regardless of how many units they sell.

In any round, if a seller's market share falls below $1/6$, she will have to declare bankruptcy. (The market manager, acting as a banker, reserves the right to force bankruptcy on firms that he deems to be in financial trouble.) Firms that have been declared bankrupt must leave the market. With bankruptcy comes limited liability. Firms that have been declared bankrupt will lose at most \$50 from their misadventure. At the end of the last round of play, those sellers who are still in business will each receive an additional payment of \$15 for each customer that they sold to in the final round. (This payment represents the value to the seller of an installed customer base.)

Sellers can vary their prices or offer discounts as they wish throughout this session. Sellers are allowed to sell at less than marginal cost or even to bribe buyers to use their operating system by selling at a negative price. At the beginning of each new round, each seller can decide whether to drop out or continue into the next round.

Session 3: Can New and Better Break in?

Will Windows' stranglehold on the computer operating system market ever be broken by Linux, Rhapsody, Be, or some hopeful monster, yet unborn?

In this session, a new operating system appears. The new system is better than any of the old systems in the sense that if it had the same number of customers as the old systems, all demanders' Buyer Values would be 50% higher.

The firm with the largest customer base in the last round of Session 2 will also be allowed to sell in Session 3. Customers who stay with the old firm will not have to pay the learning cost. Learning the new system is more

costly than learning one of the old systems. Any customer who switches operating systems will have to pay a \$20 learning cost as well as the price charged by the seller.

Warm-up Exercise

Warm-up for Session 1

The Network Externality Factors in the Picture Phone industry are given in Table 1.1.¹

Table 1.1: Network Externality Factors

If Number of Phones Sold Is in Range	Network Externality Factor Is
1–8	1
9–16	2
17–24	3
25–32	4
33–40	5
41–48	6

W 1.1 If Picture Phones sell for \$20 and 35 people buy Picture Phones, the Network Externality Factor is _____. If you buy a Picture Phone and your Initial Value is \$6, your profit (loss) will be \$ _____, if your Initial Value is 4 it will be \$ _____, and if your Initial Value is 2 it will be \$ _____.

W 1.2 If Picture Phones sell for \$5 and 48 people buy Picture Phones, the Network Externality Factor is _____. If you buy a Picture Phone and your Initial Value is \$6, your profit (loss) will be \$_____, if your Initial Value is 4 it will be \$ _____, and if your Initial Value is 2 it will be \$ _____.

¹Answers to these exercises are found on 23.

Warm-up for Session 2

The Buyer Values of all demanders for an operating system depend on the number who buy that type of system according to the schedule reported in Table 1.2. In the first round of trading, there are three firms, A, B, and C, producing three competing operating systems, OS A, OS B, and OS C. Suppose that in Round 1, OS A sells 25 units, OS B sells 10 units, and OS C sells 15 units.

Table 1.2: Buyer Values of OS

If Number of Users of OS Type Is in Range	Buyer Value Is
1–8	\$10
9–16	\$20
17–24	\$30
25–32	\$40
33–40	\$50
41–48	\$60

W 1.3 What is the Buyer Value of OS A to a demander? \$ _____ What is the Buyer Value of OS B to a demander? \$ _____ What is the Buyer Value of OS C to a demander? \$ _____

W 1.4 In Round 1, if a demander buys OS A for \$15, what is the demander's profit or loss on this round? \$ _____

W 1.5 In Round 2, suppose that a demander who bought OS B in Round 1 faces a price of \$15 for the upgraded version of OS B and a price of \$15 for OS A. If the demander buys the OS B upgrade, his profits are \$ _____ .

What are his profits if he switches to OS A? \$ _____ (Remember to take learning costs into account.)

W 1.6 In Round 1, Firm A's total costs are \$ _____ and Firm B's total costs are \$ _____ .

Warm-up for Session 3

In the last round of Session 2, Firm A had 48 customers and Firms B and C had dropped out of the market. Firm A remains in the market in Session 3, and Firm D enters the market with a new, technically superior, operating system. Suppose that the relation between Buyer Values and market share is as given in Table 1.3

Table 1.3: Buyer Values of OS

If Number of Users of OS Type Is in Range	Buyer Value of Old Technology Is	Buyer Value of New Technology Is
1–8	\$10	\$15
9–16	\$20	\$30
17–24	\$30	\$45
25–32	\$40	\$60
33–40	\$50	\$75
41–48	\$60	\$90

W 1.7 If in Round 1 of Session 3, Firm D's new operating system attracts 10 customers away from Firm A (which previously sold 48 units) what will be the Buyer Value of Firm D's operating system? \$ _____ What will be the Buyer Value of Firm A's operating system? \$ _____

W 1.8 If in Round 1, Firm D's new operating system attracts 20 customers away from Firm A, what will be the Buyer Value of Firm D's operating system? \$ _____ What will be the Buyer Value of Firm A's operating system? \$ _____

W 1.9 Suppose that buyers believe that in Round 1, Firm D's new operating system will attract 20 customers away from Firm A, and suppose that Firm A charges \$40 for the current upgrade of its operating system. What will buyers expect their profits to be if they stay with Firm A? \$ _____ Given these expectations, what price should Firm D charge if it wants buyers to expect to make \$1 more profit in this round by switching to OS D than by staying with OS A? \$ _____

Discussion of Experiment 1

Network Externalities

A product is said to exhibit **network externalities** if its Buyer Value for those who consume it is higher, the greater the number of other consumers who also consume the product.

Send-and-Receive Technologies

Some of the most striking instances of network externalities occur with products that aid communications. The value to you of a device that sends and receives messages will be larger, the greater the number of people who can receive your messages and send messages to you. For this reason, communications devices like the telegraph, telephone, fax machine, and computers connected to the internet all exhibit strong network externalities. Each of these technologies enjoyed a period of explosive growth as the value of being connected to the network increased at the same time that the network grew.

Dramatic innovations in send-and-receive technologies are not unique to the 19th and 20th centuries. Knowing how to read and write is of little value if there isn't much to read, and if few others can read the things that you write. For many centuries, literacy was confined to a very small elite. With Gutenberg's invention of the printing press in 1457, the cost of reproducing the printed word was greatly reduced, but the cost of learning to read remained high, in terms of time and effort. In many countries it was recognized that teaching people to read and write confers benefits not only on those who are taught, but also on all others who can communicate with them by the written word. As a result, many governments began to offer free public education. As literacy spreads, the ability to read and write becomes more important, and in many countries, literacy has become nearly universal. In contrast, even today there are societies where few people learn to read and write, and where the incentives to become literate remain small.

Shared Infrastructure

Another source of network externalities is the development of shared support facilities, which are known as **infrastructure**. If only a few people own high-definition television sets, they will not be of much use because

broadcasting companies will not produce many television shows in that format. If you have an Apple Macintosh computer, you hope that more people will buy Macintoshes so that software developers will write for the Mac. If only a few people in your country have automobiles, then it is difficult to find gasoline stations, repair shops, and good roads. As more people acquire automobiles, the shared infrastructure grows and owning an automobile becomes more attractive. Sony's Beta system for showing videos lost out to the VHS system as the number of VHS users increased and the number of movies available for VHS exceeded the number available for the Beta system. Consumers' willingness to pay for CD players increased drastically as more CD players were sold, because a large installed base of CD players induced record companies to record more music on CDs.

Network Externalities and the Demand Curve

We have seen that the demand curve is a powerful tool for studying markets without network externalities. Will this tool also work when there are network externalities? The answer is yes, but constructing a demand curve is a little more subtle.

Before we draw a demand curve with network externalities, let us take a second look at the demand curve for the familiar case where there are no network externalities. In previous experiments, we have drawn this demand curve by finding the quantities that are demanded at each possible price. Sometimes it is more useful to work in the other direction. That is, instead of finding the *quantity* demanded at each *price*, we find the highest *price* at which each *quantity* will be demanded.

In the case where each demander can buy up to one unit of the good, finding the highest price at which q units will be demanded is straightforward. To sell q units you will need to find q buyers, each of whom has a Buyer Value that is at least as high as the price you are asking. So how high can you set your price and still find q buyers? If you set your price equal to the q th highest Buyer Value in the market, then there will be q buyers who are willing to buy at that price. Moreover, if you try to raise the price any higher, the q th buyer will no longer want to buy, and you will not be able to sell all q units. But this tells us what we want to know. The highest price at which q units will be demanded is the q th highest Buyer Value. If we define a function $P(\cdot)$ such that $P(q)$ is the q th highest Buyer Value, then it will always be the case that q units will be demanded at the price $P(q)$. Economists sometimes call this function the **inverse demand function**.

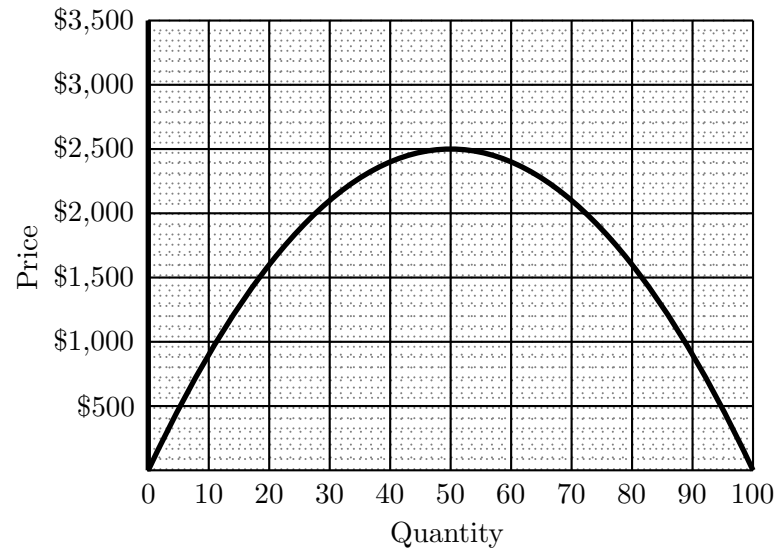
The No-Regrets Demand Curve with Network Externalities

When we draw a demand curve for a good with network externalities, it is convenient to do so by finding the price(s) at which each quantity will be demanded, much as we did in the discussion of the previous paragraph. For each quantity q , let us define $P(q)$ to be the q th highest Buyer Value *when exactly q units are sold*. The phrase in italics is needed because when there are network externalities, each demander's Buyer Value depends on the total number of units that are sold. It is useful to think of $P(q)$ as defining a "no-regrets" demand curve. Suppose that at the price $p = P(q)$, the q demanders with the largest Buyer Values all buy the good and the remaining demanders with lower Buyer Values do not buy it. In this case, no demander will have regrets about his decision to buy or not buy. Since the lowest Buyer Value of the q buyers is $P(q)$, each of them has a Buyer Value that is at least as high as the price. Therefore none of the q buyers will regret buying at price $P(q)$. The remaining *demanders that did not buy* all have Buyer Values that are no larger than $P(q)$, and therefore none of them would make a profit by buying given that the total number of items sold is q . It follows that at the price $P(q)$ none of these demanders will regret their decision not to buy.²

To fix our ideas, let us work with an example. Consider a group of 100 companies that interact occasionally with each other. They are given an opportunity to join a video conferencing network. The value to each firm of joining the network is proportional to the total number of firms that join. We will number the firms $1, 2, \dots, 100$, where Firm q is the q th largest of these firms. Larger firms find it more valuable to belong to the network than smaller firms. Firm q 's Buyer Value is equal to $\$(100 - q)$ times the total number of firms that are in the network. If k firms join the network, Firm q 's Buyer Value will be $\$(100 - q)k$. If Firm q expects exactly q firms to join the network, its Buyer Value will be $\$(100 - q)q = \$100q - q^2$. Since Firm q always has the q th highest Buyer Value, and since its Buyer Value when exactly q firms join the network is $\$100q - q^2$, it follows that $P(q) = \$100q - q^2$. In Figure 1.1 we have drawn the graph of the no-regrets demand function, $P(q) = \$100q - q^2$, for q ranging from 0 to 100.

²The careful reader will notice that if one of the demanders that is currently not buying decides to buy (and the others continue to buy) then the number of buyers would become $q + 1$, so that the demander with the $q + 1$ st highest Buyer Value may find it profitable to buy. The function $P(q)$, as we have defined it, is the no-regrets demand curve that applies either when demanders are too unimaginative to notice that if they buy they will increase the total number of users by one, or when there are so many buyers that a single additional buyer has a negligible effect on the Buyer Value of any one individual.

Figure 1.1: A No-Regrets Demand Curve



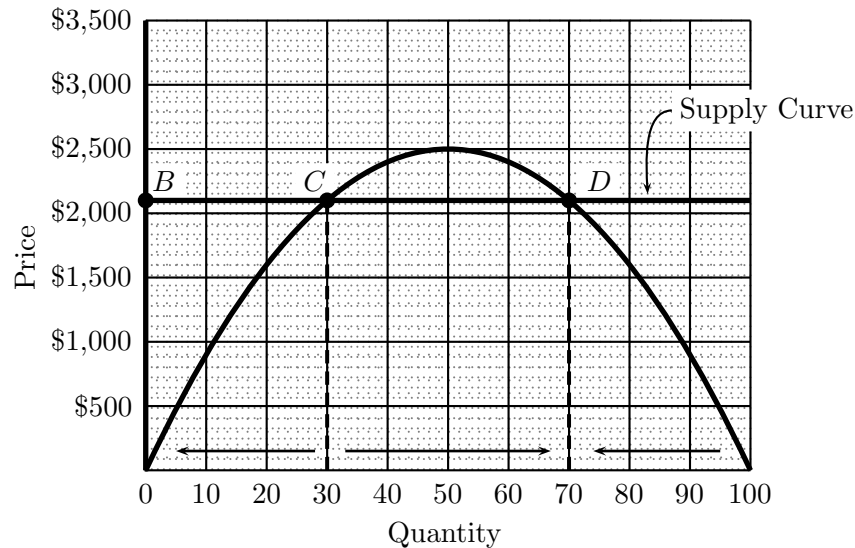
In addition to the parabola $P(q) = \$100q - q^2$, the no-regrets demand curve includes a vertical line segment extending upward from the origin. This line segment is included because if firms believe that the number of firms in the network will be zero, then every firm's Buyer Value will be 0 and no firms will want to join the network.

Equilibrium with Network Externalities

Now that we have drawn a demand curve, we can add a supply curve and find competitive equilibrium. Let us assume that the cost of adding each additional firm to the network is \$2,100. Then the supply curve for connections to the network is a horizontal line segment running across the graph at a height of \$2,100, as shown in Figure 1.2.

The supply curve crosses the demand curve at three points, which we have labeled B , C , and D , corresponding to outcomes in which the number of firms connected to the network is 0, 30, and 70. Each of these outcomes is an equilibrium quantity when the cost of joining the network is \$2,100. If everyone believes that no firms will join the network, then nobody will want to join; if everybody believes that exactly 30 firms will join the network, then exactly 30 firms will want to join; and if everybody believes that exactly 70 firms will join the network, then exactly 70 firms will want to join.

Figure 1.2: Network Supply and Demand



Stable and Unstable Equilibria

When a market has more than one equilibrium, it is often useful to investigate the **dynamics** of that market. The dynamics of any economic system describes the movement of the variables in that system over time when it is out of equilibrium. By studying the dynamics, we can often determine whether an equilibrium is likely to persist, even if the market is subject to small shocks and surprises. A **stable equilibrium** is an equilibrium such that after small movements away from equilibrium the system will return to (or very close to) the equilibrium. An **unstable equilibrium** is an equilibrium such that after very small movements away from equilibrium, the system will move even further away. A useful way to think about the difference between stable and unstable equilibrium is this: If you set a bowl on the floor and drop a marble into the bowl, the marble will roll to the bottom. If you jiggle the bowl, the marble will temporarily move away from the bottom but will soon return to its original position. This is an example of a stable equilibrium. If you invert the bowl and (carefully) set the marble on top of the bowl, the marble will stay there. But now if you jiggle the bowl, the marble will roll onto the floor and will not return to the top of the bowl. This is an example of an unstable equilibrium.

The dynamic issue that concerns us is whether the number of firms in the network will increase or decrease if it starts out at some arbitrary

quantity q . Let us assume that firms will leave the network if they are losing money and that firms will join the network if, given the current number of members, they could make a profit by joining. Suppose that the initial number of members is q . If $P(q) < \$2,100$, then Firm q , which has a Buyer Value of $P(q)$, is paying a higher price than its Buyer Value, so it will leave the network, causing q to decrease. If we look at Figure 1.2 we see that $P(q) < \$2,100$ when $0 < q < 30$ and when $70 < q \leq 100$. Therefore if q is in either of these ranges, q will decrease over time. In Figure 1.2, we have drawn leftward-pointing arrows just above the horizontal axis to show that q will decrease whenever it is in these regions.

Looking at Figure 1.2, we see that $P(30) = \$2,100$ and $P(31) > \$2,100$. Therefore if Firms 1 through 30 initially belong to the network, they will all be willing to stay. Then, since $P(31) > \$2,100$, Firm 31 would make a profit by joining the network, which would now have 31 members. We see from the graph that $P(32) > \$2,100$ and so if the network attracts 31 members, Firm 32 will join. Since $P(q) \geq \$2,100$ for all q ranging from 30 to 70, if the network gets larger than 30, it will grow until it has 70 members. In Figure 1.2, we have drawn a rightward-pointing arrow just above the horizontal axis to show that q will increase whenever it is between 30 and 70.

We can now see which of the equilibria are stable and which are unstable by looking at the arrows in Figure 1.2. If the initial quantity q is smaller than 30, the arrow points to the left and the quantity will decrease over time until it reaches 0. If the initial quantity is between 30 and 70, the arrow points to the right and the quantity will increase over time until it reaches 70. If the initial quantity is between 70 and 100, the arrow points to the left and the quantity will decrease over time until it reaches 70. Therefore the equilibrium in which 0 firms join the network and the equilibrium in which 70 firms join are both stable.

The equilibrium with 30 firms, on the other hand, is unstable. A small change in either direction will move q further away from 30. Suppose that initially, Firms 1 through 30 belong to the network. If by some accident one firm drops out of the network, then at least one of the remaining 29 firms will find it unprofitable to belong and will leave. But when this happens, the Buyer Values of the remaining firms will fall once again and another firm will leave, and so on until the network has no remaining members.³ If, on the other hand, Firm 31 decides to join Firms 1 through 30 in the network, then not only will Firm 31 make a profit, but Firm 32 can make a profit by

³Group health insurance plans occasionally fail in this way, as healthy people drop out of the plan. Such a collapse is known in the insurance industry as a “death spiral.”

joining Firms 1 through 31, and so on, until the network has 70 members.

Of the two stable equilibria, the high-level equilibrium has greater total profits. The equilibrium with no firms in the network results in zero profits for everyone, while in the 70-firm equilibrium, Firms 1 through 69 all make positive profits and the other firms make zero profits. Clearly Firms 1 through 69 would prefer the high-level equilibrium if they could reach it. Suppose that the network starts out at the equilibrium with no members. If Firms 1 through 70 all believed that the others will join, then it would be profitable for each of them to join.⁴ When we study the dynamics, we see something very interesting. To get to the high-level equilibrium from the zero equilibrium, it would not be necessary for all 70 firms to agree in advance to join. All that would be needed is to achieve a **critical mass** of 31 members. That is, the number needed to get just beyond the unstable equilibrium at 30. If Firm 31 joins, then it will be profitable for Firm 32 to join. At this point, the dominoes begin to fall. Firm 33 will be attracted by the other 32 members, and then 34, and so it goes all the way up to 70.

If your experience in the second round of Session 1 was typical, your class was able to coordinate sufficiently to reach critical mass. If this happened you probably saw a good deal of hesitation and discussion until a critical number of students bought Picture Phones, and then you saw a great rush of purchases once critical mass was reached. In large markets, where information about what others are doing is not as good as it was in your classroom, this coordination is harder to achieve. Sellers of network goods may try to reach critical mass by offering special promotions in which early purchasers get price discounts and by advertising that is intended to convince potential buyers that there are many other users of their product.

An Example with Gaps Between Buyer Values

For classroom experiments it is convenient to have a relatively small number of types of demanders. When there are a small number of types, we have a slightly more complicated demand curve with steps corresponding to gaps between the Buyer Values of one type and the next. It will be helpful to work out an example that is similar to the market for Picture Phones in Session 1.

In this example, there are 5 types of demanders and 6 demanders of each type. Demanders of Type 1 have Initial Values of 1, demanders of Type 2 have Initial Values of 2, and so on up to Type 5. The Buyer Value

⁴Firm 70 would be just indifferent.

of each demander is equal to his Initial Value multiplied by a “Network Externality Factor” that depends on the total number of units sold. Table 1.4 specifies the way that Network Externality Factors are determined by the total number of units sold.

Table 1.4: Network Externality Factors

If Number of Units Sold Is in Range	Network Externality Factor Is
1–6	1
7–12	2
13–18	3
19–24	4
25–30	5

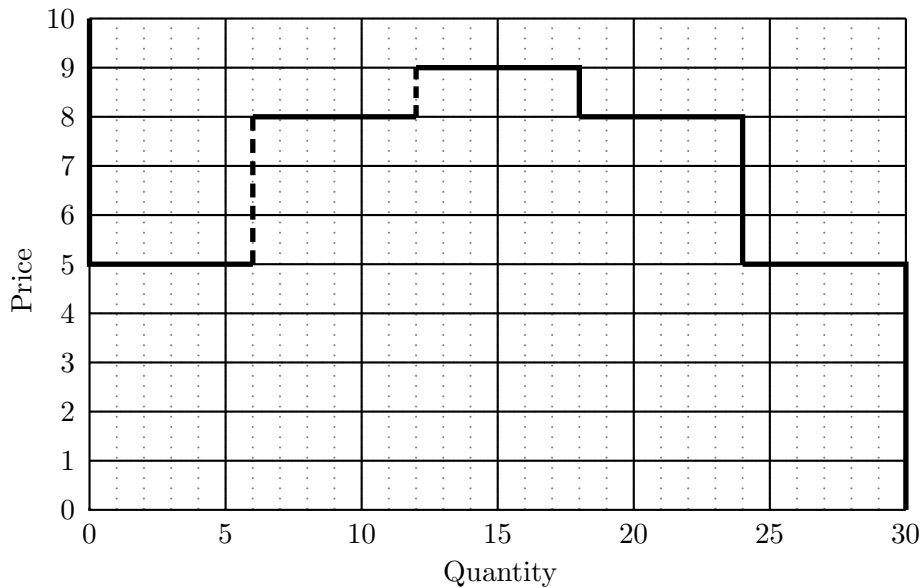
For this market, a no-regrets demand curve is drawn in Figure 1.3. To construct this curve, we first graph $P(q)$, which is the q th highest Buyer Value when the number of units sold is q . We complete the demand curve by drawing vertical lines to fill in the gaps.⁵

If q is any number from 1 to 6, the Network Externality Factor is 1. Since there are 6 demanders of each type, the demander with the q th highest Buyer Value must be a Type 5 with an Initial Value of \$5. Since $P(q)$ is equal to the Initial Value of a Type 5 times the Network Externality Factor, it follows that $P(q) = \$5 \times 1 = \5 for all q from 1 to 6. If we assume that buyers can buy fractional units, then we can “fill in the line” so that the graph of $P(q)$ includes the horizontal line segment running from $(0, 5)$ to $(6, 5)$.

If q is any number from 7 to 12, the Network Externality Factor is 2. For q in this range, the demander with the q th highest Buyer Value must be a Type 4, with Initial Value 4. Therefore for q ranging from 7 to 12, $P(q) = \$4 \times 2 = \8 . Assuming, again, that demanders can buy fractional units, the graph of $P(q)$ includes the horizontal line segment running from $(6, 8)$ to $(12, 8)$. Similar reasoning will show that for q in the range from 13 to 18, $P(q) = \$3 \times 3 = \9 ; for q in the range from 19 to 24, $P(q) = \$2 \times 4 = \8 ; and for q in the range from 25 to 30, $P(q) = \$1 \times 5 = \5 . This explains the 5 horizontal line segments on the demand curve.

⁵We have drawn the vertical lines for the “upward” jumps as dashed lines, because they are not actually on the no-regrets demand curve. Drawing the no-regrets demand curves for these intervals is a little tricky, but we don’t really need to explore these “funny bits” of the curve, since they are never stable equilibria.

Figure 1.3: A Network Demand Curve



We also need to show that the solid vertical line segments drawn in Figure 1.3 really belong on the demand curve. If the price is greater than \$5 and nobody buys the product, then the Network Externality Factor is 1 and the highest Buyer Value is only \$5, so that nobody will want to buy the good. Therefore the demand curve includes the vertical line segment that extends upward from (0, 5). Next let us show that the vertical line segment from (30, 0) to (30, 5) belongs to the demand curve. If the quantity is 30, the Network Externality Factor is 5, which implies that the lowest Buyer Value (that of the Type 1s) is $\$5 = \1×5 . Therefore at any price below \$5, all 30 demanders will make a profit by buying the product, and hence the demand curve should include all points at which the quantity is 30 and the price is less than 5. The vertical line segment running from (24, 5) to (24, 8) also belongs to the demand curve. If $q = 24$, then the Network Externality Factor is 4, and therefore at prices between \$5 and \$8, the 24 demanders of Types 2, 3, 4, and 5 would want to buy since their Buyer Values are at least $\$2 \times 4 = \8 . At these prices with $q = 24$, demanders of Type 1 are not willing to pay more than \$5. Therefore, if the price is between \$5 and \$8, and the 24 demanders of Types 2-5 buy the product, each of them will make a profit while the 6 Type 1s will not want to buy. Finally we show that the vertical line segment running from (18, 8) to (18, 9) belongs to the demand curve. If $q = 18$ the Network Externality Factor is 3. At prices between \$8

and \$9, the 18 demanders of Types 5, 4, and 3 will all want to buy since their Buyer Values are at least $3 \times 3 = \$9$. At these prices the Type 2s and Type 1s will not want to buy. Thus we have shown that each of the solid vertical line segments in Figure 1.3 belongs to the demand curve.

In the following exercise, you should determine the equilibrium quantities by finding the intersection of a horizontal supply curve with the solid portions of the demand curve in Figure 1.3.

Exercise: Finding Equilibrium

Exercise 1.1 Suppose that the cost of production is \$9.50 so that the supply curve is a horizontal line at a height of \$9.50. Draw this supply curve on Figure 1.3. What is the equilibrium number of Picture

Phones sold? _____

Exercise 1.2 Suppose that the supply curve is horizontal at a price of \$8.50. Draw the supply curve on Figure 1.3. There are two stable equilibrium quantities, _____ and _____ .

Exercise 1.3 Suppose that the supply curve is horizontal at a price of \$7.00. Draw the supply curve on Figure 1.3. There are two stable equilibrium quantities, _____ and _____ .

Exercise 1.4 Suppose that the supply curve is horizontal at a price of \$4.00. Draw the supply curve on Figure 1.3. What is the equilibrium number of Picture Phones sold? _____

Exercise 1.5 Suppose that the supply curve is horizontal at a price of \$7.00 and that initially 8 demanders buy Picture Phones. With this quantity what is the Network externality Factor? _____ Would you expect the number of phones sold to increase or decrease over time?

_____ Which of the two equilibria is the quantity likely to reach if others see that 8 people have bought Picture Phones? _____

Exercise 1.6 Suppose that the supply curve is horizontal at a price of \$7.00 and that initially only 2 demanders buy Picture Phones. With this quantity what is the Network externality Factor? _____ Given

this Network Externality Factor, how many demanders would find it profitable to buy Picture Phones? _____ If demanders will not buy Picture Phones unless they can make a profit by doing so given the current number of buyers, will more demanders buy? _____

A Brief History of the Fax Machine

The principle of the fax machine was patented in 1843 by Alexander Bain, a Scottish inventor. An Italian abbot, Giovanni Caselli, built a working version of Bain’s fax machine in 1856, which he called the pantelegraph. In 1865 Caselli established a fax system between Paris and several other French cities. Despite its promise, fax technology fell into disuse after a few years, being crowded out by the more primitive electric telegraph, which had gotten started just a few years earlier. At the turn of the century, further advances were made with the fax technology as newspapers began to use this method to send copies of photographs between cities. In the 1920s millions of dollars were spent on developing the fax and it was expected to become a common household appliance, but again it flopped. In the 1970s demand for fax machines began to grow in Japan, because Japanese, with its large number of letters is difficult to typeset.

Figure 1.4: Number of Fax Machines Shipped (in 1,000s)

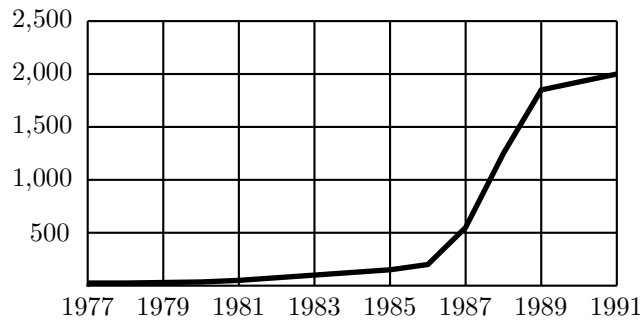


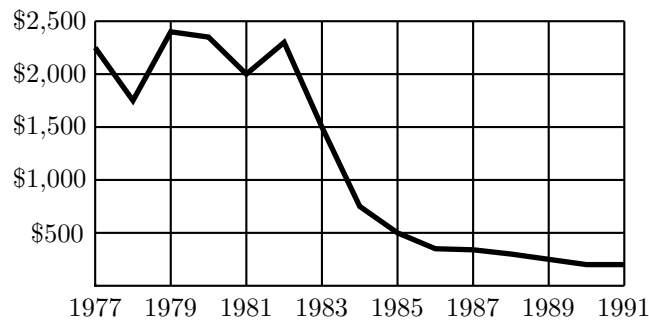
Figure 1.4 shows the growth of sales of fax machines in the United States.⁶ In 1970 there were fewer than 50,000 fax machines in existence. In the early 1980s the number of fax machines began to grow slowly. In the

⁶Figures 1.4 and 1.5 are taken from Chapter 34 of Varian [?].

late 1980s, sales of fax machines suddenly accelerated, reaching more than 2 million per year in 1991.

What caused this explosion of demand? Technical advances in the early 1980s drastically reduced the production cost of fax machines. When production costs decrease, the supply curve shifts downward. In any market we expect that a downward shift in the supply curve will result in lower prices and increased sales. Figure 1.5 shows the sharp fall in the price of fax machines that took place in the early 1980's. Between 1982 and 1984

Figure 1.5: Price of Fax Machines



the price fell from more than \$2,000 to less than \$1,000, and by 1987 it had fallen to about \$200. The increase in sales resulting from a fall in price is especially strong because of network externalities. The Buyer Values of those who have not yet purchased a fax machine rise as the number of units sold increases. The combination of rising Buyer Values and falling prices leads to dramatic increases in the number of units purchased.

You are likely to have observed a similar sequence of events in Session 1 of your classroom experiment. In the first round of the session, the price was high, and although there may have been some initial sales, Picture Phones did not catch on and those who did buy them lost money. In later rounds, as the price fell, you probably saw that a few brave souls with high Initial Values entered the market. Seeing these entrants, others with slightly lower Initial Values found it profitable to buy. And finally, as the number of entrants grew it became profitable for almost everyone to buy a Picture Phone. You were observing network externalities in action.

Competing Standards with Network Externalities

Two or more incompatible technologies that are in competition for the same demanders are said to be **competing standards**. Where there are competing standards and also network externalities, it is often the case that a demander's Buyer Value for a particular version of the product (a standard) depends more strongly on the number of other consumers who share the *same standard* than it does on the total number of consumers using other standards. Externalities of this type are said to be **standard-specific network externalities**.

Examples of Competing Standards

The market for computer operating systems is one of the most conspicuous examples of competing standards with standard-specific network externalities. If you want to share files or software with someone, or if you are looking for someone to give you good advice, it is convenient if you both use the same operating system. For these reasons, an operating system will be more useful to you the more widely it is used. Perhaps an even more important source of network externalities arises from shared infrastructure in the form of software written for each operating system. Software developers will write more software for those operating systems that are more widely used. Demanders are willing to pay more for an operating system if there is a lot of software available for it.

Today, the great majority of personal computers use the Microsoft Windows operating system. The Apple Macintosh system is much less popular, but still has some market share. Techies often prefer one or another brand of the Unix system to Windows. In the not-so-distant past, most computers used the DOS system, while other systems like NextStep and IBM's OS2 were considered possible contenders. If you look in computer magazines, you will see a good deal of discussion of possible alternative systems for the future, such as Linux (a version of Unix), Be, and Rhapsody. These future systems enjoy technical advantages over Windows, but lack the network externalities that arise from a large user base.

Within the computer industry, there are many examples of competing standards in software products. With software such as word processors or spreadsheets, it is valuable to be able to share files and knowledge with others who use the same product. The markets for these products, as well as for many other kinds of software, began with a relatively large number of competing standards that were at least partially incompatible. As use of

the product became more widespread, one of these standards came to dominate the market. For example, the first computer spreadsheet introduced was called Visicalc. Several competing products appeared, including Lotus 1-2-3, Quattro, and Microsoft Excel. Lotus overcame Visicalc's early lead to emerge temporarily as the market leader, but was not able to maintain this lead and was overtaken by the current leader, Excel, which now has by far the largest market share. In the early days of word processing, there were many competing word processors, and sharing files between them was awkward at best. The first word processor to achieve wide distribution was WordStar, which was released in 1978. Sales of WordStar rose rapidly from \$2 million in 1980 to \$70 million in 1984. In the mid-1980s, several competing products were introduced, including WordPerfect, Volkswriter, Final Word, XyWriter, and Microsoft Word. WordStar failed to keep up with technical and marketing innovations and lost market share, while WordPerfect and Word gained ascendancy. In recent years, bundled "Office Suites," which contain both a spreadsheet and a word processor (as well as some other office software) have come to dominate the market. Currently, Microsoft Office, which includes both Excel and Word, has a dominant market share.⁷

Competing standards are by no means confined to new, high-technology industries. In many parts of the country in the 1960s it was difficult for owners of Japanese cars to find parts and experienced mechanics to repair their cars. As the number of Toyotas and Hondas sold in the United States increased dramatically, parts and repairs became readily available and consequently ownership of Toyotas and Hondas became more attractive. In the period from 1887-1892, an intense battle of competing standards was fought in the emerging electric power industry between a group founded by Thomas Edison (later to become General Electric) and the Westinghouse power company.⁸ The Edison group used a direct current (DC) system and Westinghouse used alternating current (AC). Appliances that worked with one system would not work with the other. Edison had an early lead, but eventually with the help of technical improvements in alternating current technology, the Westinghouse technology prevailed. Ultimately, a converter was invented that enabled the DC power stations to be integrated into the AC power grid.

An even older example of competing standards is to be found in the

⁷In 1996, Microsoft claimed to have a 75% market share of this market. Its rival, Lotus, claimed to have a market share of 26.3%.

⁸An entertaining discussion of this battle can be found in Shapiro and Varian [?].

history of languages. If you want to communicate with someone, it is certainly helpful to speak the same language. The children of immigrants to the United States found it more useful to speak English than their parents' native tongues because this enabled them to communicate with more people. Regional languages and dialects in many parts of Europe have all but disappeared as mobility increased and people found it advantageous to communicate with a broader population. The development of English as the most-commonly-spoken second language in the world is a result not of the intrinsic merits of the English language, but simply a consequence of the network externality of being able to communicate with the large number of people in all parts of the world who use English as a first or second language.

Network Externalities, Lock-in, and Innovation

We will focus attention on three forces that play an essential role in the development of industries with competing standards:

- The presence of standard-specific network externalities
- Lock-in effects
- Rapid technical improvement

If you have a Macintosh computer and you want to switch to a Windows system, you will have to learn a whole new set of commands and conventions. You will find that your old software doesn't work on your new computer, so you will also have to replace your software. If you want to switch word processors, you need to learn new keyboard commands. If you have a tape deck for playing records and you want to switch to a CD player, you will have to replace your record collection. If you run an airline and you want to replace your fleet of Boeing airplanes with planes made by Airbus, you will have to retrain your crew to fly the new planes and your mechanics to work on them. If you grew up in Turkey and want to live in Germany, you will probably have to learn German.

We say that there is **lock-in** when it is costly to switch from one competing standard to another. The customers who are currently using a product are known as the product's **installed customer base**. As we discovered in a previous experiment, in the long run in industries like the restaurant industry where there is free entry and no lock-in, firms' profits are likely to be driven to zero. In industries with competing standards and lock-in effects, the pressure from potential entrants is less severe. The presence of lock-in gives an advantage to a firm with a large installed customer base because

its current users are not likely to switch products unless the advantages of the alternative product exceed the cost of switching.

We have found two reasons to expect that a dominant firm with a large installed customer base will be able to keep its customers even if it charges higher prices than its competitors. First, there are standard-specific network externalities, which means that demanders have higher Buyer Values for the dominant firm simply because of its large customer base. In addition to these network externalities, because of switching costs, its current customers are willing to maintain and upgrade the product that they are currently using even if it is somewhat more expensive than competing products.

Both of these forces suggest that a firm that takes an early lead in an industry with network externalities and lock-in should be able to increase its lead and ultimately drive out its competitors. Yet when we look at the history of such industries, we see that the early leaders do not always win the dominant market share. Apple Computer had an early lead both in hardware and in operating systems, but it is now a relatively minor player. WordStar was the first commercially successful word processor and is now defunct. WordPerfect gained the leading market share and then lost it to Word. Visicalc, the first spreadsheet, was crowded out by Lotus, which in turn has lost most of its share to Excel. Why were these early leaders unable to take advantage of network externalities and lock-in to achieve market dominance? Perhaps the main threat to an entrenched firm is technological innovation. If innovators can produce a new standard that is much better than that offered by the currently dominant firm, they may be able to persuade users to switch, despite the costs. A second threat arises when the challengers realize that a large installed customer base is a valuable asset—an asset worth paying for. In order to gain this asset, challengers may be willing to bear large early losses in order to break into the market. Since the prize is large, they are willing to spend a lot of money on research and advertising, and are willing to discount their product aggressively in order to attract customers away from the dominant firm.

In classroom experiments, sellers who gain the largest market share in Round 1, and thus generate the highest Buyer Values, are eager to capitalize on their advantage, and often increase their prices in Round 2. At the same time, the sellers with low market shares realize the importance of gaining market share, and often charge very low prices (especially to new customers).⁹ As a result, the firm that has the largest market share in the first round often loses its share by the end of the second or third round.

⁹Occasionally they offer their product for free or even bribe customers to accept it.

Further Reading

The economics of network externalities is a relatively new area, but one in which some very interesting work is being done. As far as we know, the most accessible and thorough textbook discussion available is Chapter 34 of *Intermediate Microeconomics* by Hal Varian [?]. If you are tired of textbooks and want to read a more lively discussion with lots of real-world examples, we strongly recommend *Information Rules* by Varian and his coauthor Carl Shapiro [?]. If you guessed that there must be a good internet site devoted to network externalities, you guessed right. The place to look is Nicholas Economides' Internet Site for Network Economics, which is located at <http://raven.stern.nyu.edu/networks/site.html>.

Answers to Warm-up Exercises

W 1.1: 5, $\$(6 \times 5) - \$20 = \$10$, $\$(4 \times 5) - \$20 = \$0$, $\$(2 \times 5) - \$20 = -\$10$; **W 1.2:** 6, $\$(6 \times 6) - \$5 = \$31$, $\$(4 \times 6) - \$5 = \$19$, $\$(2 \times 6) - \$5 = \$7$; **W 1.3:** \$40, \$20, \$20; **W 1.4:** $\$40 - \$15 - \$15 = \10 ; **W 1.5:** $\$20 - \$15 = \$5$, $\$40 - \$15 - \$15 = \10 ; **W 1.6:** $\$75 + (5 \times 25) = \200 , $\$75 + (5 \times 10) = \125 ; **W 1.7:** \$30, \$50; **W 1.8:** \$45, \$40; **W 1.9:** \$0, \$24.

Answers to Exercises

Ex. 1.1: 0; **Ex. 1.2:** 0, 18; **Ex. 1.3:** 0, 24; **Ex. 1.4:** 30; **Ex. 1.5:** 2, increase, 24 units; **Ex. 1.6:** 1, 0, No.

Lab Notes for Experiment 1

Market Data for Session 1

Your instructor will post a table showing how network externality factors in Session 1 are related to the number of units sold. Record this information by completing the first column of Table 1.5.

Table 1.5: Network Externality Factors: Session 1

If Number of Units Sold Is in Range	Network Externality Factor Is
	1
	2
	3
	4
	5
	6

In Table 1.6, record the price of Picture Phones, the number of Picture Phones sold, and the Network Externality Factor in each round.

Table 1.6: Prices in Session 1

Round Number	1	2	3	4
Price of Picture Phones				
Number of Phones Sold				
Network Externality Factor				

Your instructor will post the number of demanders with each possible Buyer Value who participated in Session 1. Record this information in Table 1.7.

Table 1.7: Distribution of Initial Values

Initial Value	Number of Demanders
1	
2	
3	
4	
5	
6	

Your instructor will also post the number of demanders with each Initial Value *who bought Picture Phones* in each round of Session 1. Record this information in Table 1.8.

Table 1.8: Buyers by Initial Value

Initial Value	Number of Buyers			
	Round 1	Round 2	Round 3	Round 4
1				
2				
3				
4				
5				
6				

Use the information posted by your instructor to complete Tables 1.9, 1.10, and 1.11 for Session 2, and Tables 1.12 and 1.13 for Session 3. For each firm and for each round, enter the total number of units sold by the firm, the highest and lowest prices that it received for units sold, and its total revenue.

Table 1.9: Firm A in Session 2

Round	Units Sold	Highest Price	Lowest Price	Total Revenue
1				
2				
3				
4				

Table 1.10: Firm B in Session 2

Round	Units Sold	Highest Price	Lowest Price	Total Revenue
1				
2				
3				
4				

Table 1.11: Firm C in Session 2

Round	Units Sold	Highest Price	Lowest Price	Total Revenue
1				
2				
3				
4				

Table 1.12: Old Firm in Session 3

Round	Units Sold	Highest Price	Lowest Price	Total Revenue
1				
2				
3				
4				

Table 1.13: New Firm in Session 3

Round	Units Sold	Highest Price	Lowest Price	Total Revenue
1				
2				
3				
4				

NAME _____ SECTION _____

Homework for Experiment 1

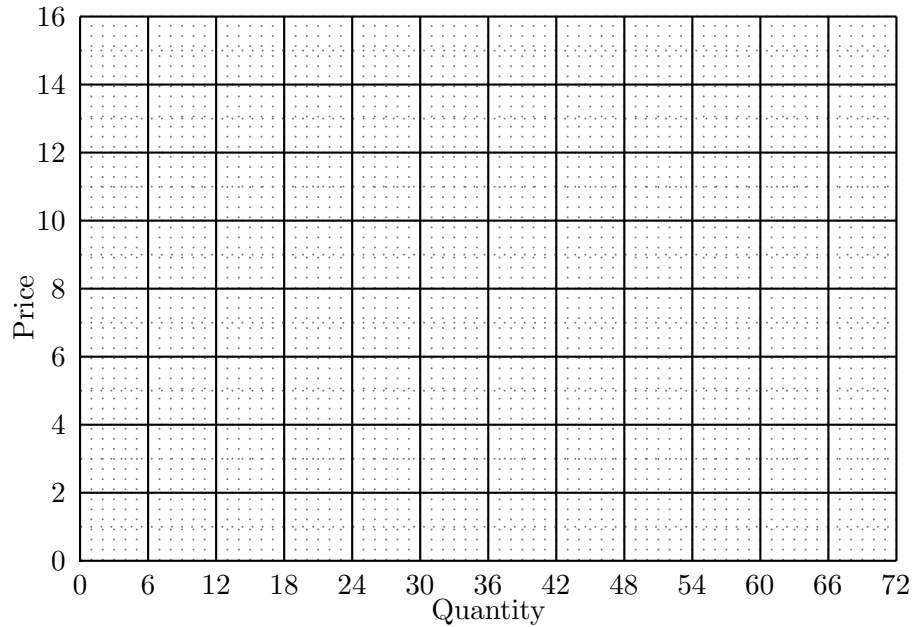
Problem 1.1 We defined $P(q)$ to be the q th highest Buyer Value when the number of buyers is q . (See page 9.) For Session 1, $P(q)$ will be equal to the q th highest Initial Value times the Network Externality Factor when q units are sold. For each q , you can use Table 1.7 to determine the q th highest Initial Value, and you can use Table 1.5 to find the Network Externality Factor when q units are sold. In this experiment, there are 6 ranges of quantities such that $P(q)$ is constant over each range. Complete Table 1.14 to show $P(q)$ for each of these ranges.

Table 1.14: Table for $P(q)$

Quantity Range	$P(q)$ in this Range
1 to ____	\$6
____ to ____	\$10
____ to ____	
____ to ____	
____ to ____	
____ to ____	

Problem 1.2 In Figure 1.6, graph the no-regrets demand curve for Session 1. **Hint:** You can use the information in Table 1.14 to graph $P(q)$. Add a vertical line segment corresponding to zero sales at each price above \$6 and draw vertical line segments to fill in the jumps between the horizontal line segments in your graph of $P(q)$. See the discussion on page 13, where we drew a curve for a similar case.

Figure 1.6: No-Regrets Demand Curve: Session 1



Problem 1.3 On Figure 1.6, draw a horizontal supply curve at a price of \$15. What is the equilibrium quantity at this price? _____

Problem 1.4 In Round 1 of Session 1, the price was \$15.

How many Picture Phones were sold in this round? _____

How many of the buyers made positive profits? _____

How many of the buyers took losses? _____

If there had been a second round where the price was still \$15, how many

Picture Phones do you think would have been sold? _____

Problem 1.5 On Figure 1.6, draw a horizontal supply curve at a price of \$11. What are the two stable equilibrium quantities when the supply curve is horizontal at \$11? _____

Problem 1.6 In Round 2 of Session 1, the price was \$11.

How many picture phones were sold in this round? _____

Which of the two equilibrium quantities was closer to the outcome of the experiment? _____

How many of the buyers made positive profits? _____

How many of the buyers made losses? _____

Problem 1.7 On Figure 1.6, draw a horizontal supply curve at a price of \$9. What are the two stable equilibrium quantities when the supply curve is horizontal at \$9? _____

Calculate the total amount of profits that buyers would make in the equilibrium with the higher quantity. \$ _____

Suppose that initially the market was stuck at a low-level equilibrium where nobody would buy a Picture Phone at a price of \$9 and the government offered to sell Picture Phones for \$5 to the first k buyers, where k is the number of demanders with Buyer Value \$6. What do you think would happen to the total number of Picture Phones sold? _____